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Original Article

Association between sleep and residential environments in the summertime in Japan

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ABSTRACT

Objectives: We aimed to identify the effect of environmental factors on sleep in the summertime in Japan.
Methods: A self-reported questionnaire survey was conducted in Japan. Age of participants ranged from 20 to 70 years.
Results: The mean Pittsburgh Sleep Quality Index (PSQI) score was 4.9 (±2.7), and 123 (35.0%) participants had scores of >5. According to the results of multivariate logistic regression analysis, the adjusted odds ratio (aOR) for PSQI scores of >5 without installation of air conditioner was 1.8 (95% confidence interval [CI], 1.0–3.3; $P < .05$), use of a light bulb was 3.7 (95% CI, 1.1–12.6; $P < .05$), and noise was 2.1 (95% CI, 1.1–4.1; $P < .05$) after controlling for several confounding variables. Difficulty initiating sleep (DIS) was associated with installation of an air conditioner (1 [reference] to 3 [aOR, 2.5 {95% CI, 1.2–5.1}] and 4 [aOR, 2.8 {95% CI, 1.1–7.1}]) and noise (1 [reference] to 3 [aOR, 2.4 {95% CI, 1.0–5.9}] and 4 [aOR, 8.8 {95% CI, 3.1–25.0}]). Difficulty maintaining sleep (DMS) was associated with installation of a fan (1 [reference] to 2 [aOR, 0.4 {95% CI, 0.2–0.8}] and noise (1 [reference] to 3 [aOR, 2.3 {95% CI, 1.0–5.3}]) after controlling for several confounding variables.
Conclusions: Our finding using analysis of the association between residential environments and subjective sleep statuses, which determined that the installation of an air conditioner and lighting equipment might affect sleep, may be useful to discuss sleep environments and improve sleep quality.

1. Introduction

The maximum temperature and the average temperature have been rising worldwide with the progress of global warming [1]. According to the Japan Meteorological Agency, Japan's annual average temperature has shown a 1.15 °C increase in the last 100 years, and the number of days when the temperature was high also has increased since the 1990s [2]. The number of sultry nights when the temperature does not fall below 25 °C outdoors also has been increasing year by year, and it may cause heat-related sleep disorders in addition to other serious health problems such as heat stroke [3].

There have been several elderly men and women who experienced heat disorders in their bedrooms and it has been postulated that their bedrooms may not be safe and comfortable for sleep [4]. There are some sleep experimental studies on the association between sleep quality and ambient temperature which suggest that ambient temperature affects sleep architectures [5–7]. Okamoto-Mizuno et al. [7] reported that conditions under 35 °C caused an increase in awakening and a decrease in sleep efficiency and slow-wave sleep compared to conditions under 29 °C. A previous survey on the sleep environment among elderly individuals in Tokyo, Japan, found that many slept without the use of an air conditioner most of the time in summer, as they believed that the nighttime use of air conditioning was bad for their health [8], even though sultry nights occurred on over 50 days in Tokyo in 2010 [9]. In another study, it was reported that 88% of indoor heat stroke patients did not use an air conditioner, and 50% did not even use

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a fan or open the windows [10]. Because of these circumstances, the risk for having a sleep disorder due to heat exposure might be high in the summertime in Japan.

The light environment also is important for sleep. Nocturnal light exposure to bright lights and short wavelength lights induces suppression of melatonin secretion and delays the circadian rhythm [11–13]. During the last decades, the opportunity for exposure to those lights has been increasing with products including short wavelength components becoming widespread as well as with increasing access to 24-h supermarkets and convenience stores where high intensity lighting is used all night.

It may be possible to prevent sleep disorders by improving the inside house environment (i.e., by the installation of cooling devices and changing illumination devices). Thus we conducted our study in one of the hottest places in Japan to identify risk factors including residential environments for sleep disorders in the summertime.

2. Materials and methods

2.1. Study area and subjects

We conducted the survey in Tajimi City, Gifu prefecture, Japan (Fig. 1). The target area recorded 40.9 °C in 2007, which is the highest temperature in recorded history in Japan, making it one of the hottest places in Japan. One thousand individuals aged 20 years or older were selected by random sampling from the basic resident register and self-reported questionnaires were distributed to the individuals by mail, asking them to reply by August 2012.

2.2. Measures

The questionnaire contained sociodemographic characteristics, including age [14–19], gender [15,18,20,21], working status [15,17,18], and marital status [15,18,22,23]; lifestyle, including alcohol consumption [19,24–26], smoking [27,28], exercise [17,25,29], and napping [30]; psychologic and health conditions, including perceived health status [17,20,31], life satisfaction [17], psychologic stress [17], and ability to cope with stress [17]; residential environment; and sleep status.

Variables about residential environment were: type of housing (detached or apartment); bedroom setup (bedroom only for sleeping or bed cum sitting room) and its direction; installation of cooling device (air conditioner, fan, or nothing); how the participant copes with heat during sleep (use of cooling device, open windows, use of cooling items [i.e., ice pillow, nothing]); type of bed (bed or futon); sleeping with someone in the same room or not; noises often heard in the night; types of curtain; use and color (i.e., white, orange) of lighting in the evening.

To assess sleep quality and disturbances in the last month, we used the Pittsburgh Sleep Quality Index (PSQI) Japanese version [32]. The PSQI has 18 individual items and generates 7 component scores (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction). The PSQI score ranges from 0 to 21, and a score of >5 indicates that a subject is having severe difficulties in at least two areas or moderate difficulties in more than three areas [33].

2.3. Statistical analysis

The Mann–Whitney *U* test and Kruskal–Wallis test were used for comparison between variables. Binomial logistic regression analysis was performed to identify risk factors for PSQI scores (below five or over six). Multinomial logistic regression analyses also were performed in which response variables were difficulty initiating sleep (DIS) (Question 5a: "Do you have difficulty falling asleep within 30 min?") and difficulty maintaining sleep (DMS) (Question 5b: "Do you wake up in the middle of the night or early morning?" 1 = not during the past month; 2 = less than once a week; 3 = once or twice a week; 4 = three or more times a week). The degree of risk was represented as adjusted odds ratios (aOR) for age, gender, perceived health status, life satisfaction, psychologic stress, type of bedroom, noise, installation of air conditioner, installation of fan, and type of lighting. Statistical procedures were conducted using SPSS statistics 19.

Ethical approval for our survey was granted by the Institutional Research Ethics Committee of the University of Tsukuba.

3. Results

We received 443 questionnaires from the participants (response rate, 44.3%). There were 351 responses which satisfactorily answered all question items, enabling the calculation of a PSQI score. In comparison to available respondents, the prevalence of unavailable respondents was 26.0% in women and 11.7% in men, and there was a statistically significant gender difference (χ^2 test $P < .001$). Age ($P < .05$) and waking up frequently in the middle of the night or early morning ($P < .05$); getting up frequently to use the bathroom ($P < .001$); feeling pain ($P < .05$); and needing to take medicine to help the participant sleep ($P < .05$) were significantly higher in unavailable respondents than in available respondents (Mann–Whitney *U* tests).

3.1. Characteristics of the respondents

The participants' ages ranged from 20 to 70 years, and the number of men and women was 142 (40.5%) and 209 (59.5%), respectively. Table 1 shows the structure of the population and sample. The number of fulltime workers, part-time workers, and unemployed participants was 152 (43.3%), 78 (22.2%), and 119 (33.9%), respectively. In addition, the number of married participants was 263 (74.9%) and 335 participants (95.4%) lived with their family. Regarding lifestyle, 91 participants (25.9%) reported alcohol consumption, 49 (14.0%) participants reported a smoking habit, 183 (52.1%) participants reported exercising, and 216 (61.5%) participants reported having sufficient leisure time. Regarding psychologic and health conditions, 308 (87.7%) participants reported having an adequate perceived health status, 228 (65.0%) participants reported being satisfied with their life, 196 (55.8%) participants reported having psychologic stress, and 287 (81.8%) participants reported having the ability to cope with stress.

3.2. Residential environment

There were 316 (90%) participants who reported living in a detached house and 34 (9.7%) participants reported living in apartment housing. The most common direction of bedrooms was facing south 187 (53.3%), followed by facing east ($n = 64$ [18.2%]), facing north ($n = 41$ [11.7%]), and facing west ($n = 34$ [9.7%]). There were 241 (68.7%) of participants who had a bedroom just for sleeping and 102 (29.1%) who had a bed cum sitting room. Regarding installation of a cooling device in the bedroom, 244 (69.5%) participants had an air conditioner, 235 (67.0%) participants had a fan, and 21 (6.0%) participants had neither. To cope with the heat, 295 (84.0%) participants used an air conditioner or fan, 212 (60.4%) participants opened their windows, 51 (14.5%) participants used cooling items, and 5 (1.4%) did nothing (multiple responses). Regarding type of bed, 180 (51.3%) participants slept on a futon and 166 (47.3%) participants slept in a bed. In addition, 195 (55.6%) participants slept with someone in the same bedroom.

Fig. 1. Tajimi city in Gifu prefecture.

Table 1
Characteristics of survey sample and the population in Tajimi city.

Characteristic	Population (%)		Sample (%)		Actual sample (%)	
	Men	Women	Men	Women	Men	Women
	49.5	50.5	47.8	52.2	40.7	59.3
Age group (y)						
20–29	7.8	7.8	8.3	7.5	4.0	6.0
30–39	9.5	9.3	8.9	10.2	5.7	10.0
40–49	10.2	10.2	9.9	10.5	7.7	12.0
50–59	9.5	10.1	10.3	10.8	10.6	15.2
60–70	12.4	13.1	10.4	13.2	12.3	28.4
Total (*n*)	77,279		1000		351	

Abbreviation: y, years.

Regarding noise at night, there were 74 (21.1%) participants who answered "yes" to hearing noise at night and the noises were related to traffic, such as cars, motorcycles, and trains; household noise; and sounds of animals, such as dogs, cats, frogs, and insects. There were 340 (96.9%) participants who reported using curtains for the windows in their bedroom and 10 (2.8%) who reported using nothing. The most frequently used lighting was fluorescent lights ($n = 249$ [70.9%]), followed by light bulbs ($n = 38$ [10.8%]) and light-emitting diode (LED) lighting ($n = 34$ [9.7%]). The lighting colors used were white ($n = 280$ [79.8%]) and orange ($n = 54$ [15.4%]).

3.3. Sleeping habits

The mean bedtime of participants was 11:40 pm (±93 min), and the mean wake up time was 06:12 am (±73 min). The mean sleep latency was 21.1 (±20.2) min, and the mean sleep duration was 6.9 (±1.6) h. There were 190 (54.1%) participants who reported the habit of taking a nap once or more a week, and the mean time for napping was 2.6 (±2.9) h per week. The mean PSQI score was 4.9 (±2.7) and 123 (35.0%) participants had a score of >5. The mean of DIS score and DMS scores were 1.9 (±1.9) and 2.2 (±1.1),

Table 2
Basic information on Pittsburgh Sleep Quality Index scores, difficulty initiating sleep, and difficulty maintaining sleep among the 351 participants in our study.

Variables	Subgroup	n	PSQI scores		DIS		DMS	
Total		351	4.9 ± 2.7		1.9 ± 1.0		2.2 ± 1.1	
Age (y)	20–59	249	5.0 ± 2.7		1.8 ± 1.0	**	2.2 ± 1.1	
	≥60	100	4.8 ± 2.1		2.1 ± 1.0		2.4 ± 1.1	
Gender	Men	142	4.8 ± 2.8		1.8 ± 1.0		2.1 ± 1.2	
	Women	209	5.0 ± 2.6		1.9 ± 1.0		2.3 ± 1.1	
Job	Employed	230	4.8 ± 2.5		1.7 ± 1.0	***	2.2 ± 1.2	
	Unemployed	119	5.1 ± 2.9		2.2 ± 1.1		2.3 ± 1.1	
Marital status	Married	263	4.7 ± 2.5		1.8 ± 1.0		2.2 ± 1.2	
	Not married	85	5.5 ± 3.0		2.1 ± 1.1		2.3 ± 1.1	
Live with a family	Yes	335	4.9 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
	No	16	5.3 ± 3.5		2.1 ± 1.3		2.3 ± 1.1	
Alcohol intake	≥4 d/wk	91	4.4 ± 2.5	*	1.8 ± 1.0		2.2 ± 1.1	
	<4 d/wk	260	5.1 ± 2.7		1.9 ± 1.0		2.2 ± 1.1	
Smoking habit	Yes	49	5.6 ± 2.7		2.1 ± 1.2		2.2 ± 1.1	
	No	302	4.8 ± 2.6		1.8 ± 1.0		2.2 ± 1.1	
Regular exercise	Yes	183	4.6 ± 2.6	*	1.9 ± 1.0		2.2 ± 1.1	
	No	168	5.3 ± 2.7		1.9 ± 1.0		2.3 ± 1.2	
Self-rated health	Good	308	4.6 ± 2.5	***	1.8 ± 1.0	**	2.2 ± 1.1	**
	Poor	36	7.2 ± 3.3		2.4 ± 1.3		2.8 ± 1.2	
Enough leisure time	Yes	216	4.5 ± 2.5	***	1.9 ± 1.0		2.1 ± 1.1	**
	No	132	5.6 ± 2.7		1.9 ± 1.0		2.5 ± 1.2	
Life satisfaction	Yes	228	4.3 ± 2.4	***	1.8 ± 1.0		2.1 ± 1.1	***
	No	120	6.1 ± 2.7		2.0 ± 1.1		2.5 ± 1.1	
Stress	Yes	196	5.8 ± 2.0	***	2.0 ± 1.1	**	2.5 ± 1.2	***
	No	150	3.7 ± 2.1		1.7 ± 0.9		1.9 ± 1.0	
Coping with stress	Yes	287	4.6 ± 2.4	***	1.8 ± 0.9	**	2.2 ± 1.1	*
	No	54	6.7 ± 3.3		2.3 ± 1.2		2.6 ± 1.2	
Building	Detached	316	4.8 ± 2.6		1.8 ± 1.0		2.2 ± 1.1	
	Apartment	34	5.6 ± 3.0		2.1 ± 1.2		2.4 ± 1.1	
Prospect of bedroom	North	41	4.4 ± 2.9		2.0 ± 1.1		2.2 ± 1.2	
	South	187	4.9 ± 2.5		1.8 ± 1.0		2.2 ± 1.1	
	East	64	4.8 ± 2.7		1.9 ± 1.0		2.2 ± 1.2	
	West	34	5.7 ± 3.4		1.9 ± 1.1		2.5 ± 1.2	

(*continued on next page*)

Bedroom	Only for sleeping	241	4.6 ± 2.5	**	1.8 ± 1.0		2.2 ± 1.1	*
	Bed cum sitting room	102	5.7 ± 2.8		2.0 ± 1.1		2.4 ± 1.1	
Installation of air conditioner in bedroom	Yes	244	4.8 ± 2.5		1.8 ± 1.0	**	2.2 ± 1.1	
	No	107	5.1 ± 2.9		2.1 ± 1.1		2.3 ± 1.1	
Installation of fan in bedroom	Yes	235	4.9 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
	No	116	4.9 ± 2.7		1.8 ± 1.0		2.2 ± 1.2	
Installation of cooling device	Neither air conditioner nor fan	21	5.4 ± 3.2		2.2 ± 1.2		2.4 ± 1.2	
	At least one cooling device	330	4.9 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
Bedding	Futon	180	4.8 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
	Bed	166	5.0 ± 2.7		1.9 ± 1.0		2.2 ± 1.1	
Sleep together in the same room	Yes	195	4.7 ± 2.5		1.8 ± 1.0		2.2 ± 1.1	
	No	154	5.2 ± 2.9		2.0 ± 1.1		2.3 ± 1.1	
Noise in the night	Yes	74	6.0 ± 2.6	***	2.3 ± 1.1	***	2.5 ± 1.1	**
	No	276	4.6 ± 2.6		1.8 ± 1.0		2.1 ± 1.1	
Using curtain	Yes	340	4.9 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
	No	10	5.5 ± 4.1		1.6 ± 1.1		2.9 ± 1.1	
Lighting equipment	Light bulb	38	5.3 ± 2.6		1.9 ± 1.0		2.3 ± 1.2	
	Fluorescent light	249	4.9 ± 2.7		1.9 ± 1.0		2.2 ± 1.1	
	Light-emitting diode lamp	34	4.5 ± 2.3		1.9 ± 1.0		2.4 ± 1.1	
Lighting color	White	280	5.0 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	
	Orange	54	4.5 ± 2.6		1.9 ± 1.0		2.2 ± 1.1	

Abbreviations: PSQI, Pittsburgh Sleep Quality Index; DIS, difficulty initiating sleep; DMS, difficulty maintaining sleep; y, years; d, day; wk, week.
(1 = not at all in one week; 2 = less than once a week; 3 = once or twice a week; and 4 = three or more times a week).
Significant differences were marked as *$P < .05$, **$P < .01$, and ***$P < .001$.

respectively. The association between these scores and variables is shown in Table 2.

3.4. Environmental factors related to sleep (multiple logistic regressions)

Binary logistic regression analysis revealed that PSQI scores were associated with installation of an air conditioner, type of lighting, and presence of noise. The aOR for a PSQI score of >5 reporting no installation of an air conditioner was 1.8 (95% confidence interval [CI], 1.0–3.3 [$P < .05$]); reporting the use of a light bulb was 3.7 (95% CI, 1.1–12.6 [$P < .05$]), and reporting the presence of noise was 2.1 (95% CI, 1.1–4.1 [$P < .05$]) after controlling for several confounding variables. Other risk factors are shown in Table 3.

The result of multinomial logistic regression is shown in Table 4. DIS was associated with installation of an air conditioner

Table 3
Binomial logistic regression analysis (adjusted odds ratio of Pittsburgh Sleep Quality Index score of >5).

Variables	Subgroup	aOR	95% CI	
Age (y)	20–59	1.0		
	⩾60	2.0	1.1–3.8	*
Gender	Men	1.0		
	Women	1.1	0.6–1.9	
Self-rated health	Good	1.0		
	Poor	2.5	1.0–6.1	*
Life satisfaction	Yes	1.0		
	No	1.6	0.9–3.0	
Stress	No	1.0		
	Yes	4.1	2.1–8.1	***
Bedroom	Only for sleeping	1.0		
	Bed cum sitting room	1.4	0.8–2.5	
Noise in the night	No	1.0		
	Yes	2.1	1.1–4.1	*
Installation of air conditioner in bedroom	Yes	1.0		
	No	1.8	1.0–3.3	*
Installation of fan in bedroom	Yes	1.0		
	No	1.0	0.6–1.7	
Lighting equipment	Light-emitting diode lamp	1.0		
	Light bulb	3.7	1.1–12.6	*
	Fluorescent light	2.1	0.8–5.7	

Abbreviations: aOR, adjusted odds ratio; 95% CI, 95% confidence interval; y, years.
Significant differences were marked as *$P < .05$, **$P < .01$, and ***$P < .001$.
Model χ^2 test ($P < .001$); Hosmer–Lemeshow tests ($P = .69$).

(1 [reference] to 3 [aOR, 2.5 {95% CI, 1.2–5.1}] and 4 [aOR, 2.8 {95% CI, 1.1–7.1}]) and noise (1 [reference] to 3 [aOR, 2.4 {95% CI, 1.0–5.9}] and 4 [aOR, 8.8 {95% CI, 3.1–25.0}]) after controlling for several confounding variables. DMS was associated with installation of fan (1 [reference] to 2 [aOR, 0.4 {95% CI, 0.2–0.8}] and noise (1 [reference] to 3 [aOR, 2.3 {95% CI, 1.0–5.3}]). Other risk factors are shown in Table 4.

4. Discussion

4.1. Characteristics of survey area and subjects

The mean daily maximum temperature [9] in Tajimi city was 31.9 °C in July and 34.8 °C in August in 2012. The mean daily minimum temperature was 22.4 °C in July and 23.0 °C in August, and the number of nights when the temperature did not fall below 25 °C was fewer than in urban areas, such as Tokyo, Nagoya, among others [9].

In regard to the population composition of Tajimi city, there were 49.5% men (48.7% throughout Japan) and 50.5% women (51.3% throughout Japan) There was a juvenile population of 13.5% (13.2% throughout Japan), a productive age population of 64.8% (63.8% throughout Japan), and an aging population of 21.7% (23.0% throughout Japan) [34,35]. Furthermore, the mean sleep duration was almost the same for the subjects (6.9 h) and the mean of Japanese individuals (7.2 h) [36].

4.2. Residential environment and subjective sleep status in the summertime

4.2.1. Installation of air conditioner

In total 69.5% of participants had an air conditioner in their bedroom, and there were only 6% of participants who had neither an air conditioner nor a fan. The result of the multivariate analysis was that the installation of an air conditioner was associated with sleep variables. This finding suggests that participants who did not install either one in their bedroom were at increased risk for a PSQI score >5 and DIS. Although 84.0% of participants responded that they used an air conditioner or fan, there also was a 60.4% response rate of participants who reported opening their windows; therefore, we believe that the participants did not use their air conditioners all night and sometimes used a fan or opened the windows, despite the installation of an air conditioner in their bedrooms. In a previous study [8] on the use of air conditioning at night among elderly individuals, there were only 13.6% of participants who reported using an air conditioner all night, and more than half of the subjects used a timer function; furthermore, 80% of the participants set the timer for less than 3 h. In the cases of an air conditioner installed in the bedroom, it is assumed that many participants used their air conditioner when falling sleep, and thus the risk for DIS was lower. According to studies of sleep experiments, when the ambient temperature was set at 26 °C in the first 3 h, the rise in temperature induced an increase in awakening and lowered sleep efficiency in contrast to the condition in which the ambient temperature was set at 26 °C all night [37]. Use of the air conditioner timer function in the early period is effective for falling asleep; however, the room temperature rises often after the timer goes off and increases awakening during sleep. Thus using an air conditioner all night might be more suitable on sultry nights.

4.2.2. Lighting equipment

The most commonly reported lighting equipment in the room where participants spent time in the evening was fluorescent light (70.9%). In Japan, fluorescent lights have been used as domestic lighting fixtures for a few decades. Our multivariate analysis revealed that lighting equipment was associated with variable PSQI scores. We observed that using light bulb was a risk factor for a PSQI score of >5 compared to using LED lighting. However, LED lighting has shorter wavelength and stronger intensity of illumination than light bulbs. Nocturnal short wavelength light exposure elicits suppression of melatonin secretion [11] and affects sleep [12]. Thus we cannot consider lighting equipment as a direct cause

Table 4
Multinomial logistic regression analysis (adjusted odds ratio of difficulty initiating sleep and difficulty maintaining sleep).

		DIS			DMS		
		aOR	95% CI		aOR	95% CI	
2 Age (y)	20–59	1.0			1.0		
	⩾60	2.6	1.3–5.2	**	0.9	0.4–2.0	
Gender	Men	1.0			1.0		
	Women	1.4	0.8–2.6		1.7	0.9–3.4	
Self-rated health	Good	1.0			1.0		
	Poor	1.0	0.3–3.0		1.0	0.3–3.7	
Life satisfaction	Yes	1.0			1.0		
	No	0.8	0.4–1.7		1.3	0.6–3.1	
Stress	No	1.0			1.0		
	Yes	1.6	0.8–3.2		0.7	0.4–1.6	
Bedroom		1.0			1.0		
Only for sleeping							
Bed cum sitting room		1.4	0.7–2.7		1.8	0.9–3.6	
Noise in the night	No	1.0			1.0		
	Yes	1.5	0.7–3.5		1.2	0.5–2.9	
Installation of air conditioner in bedroom	Yes	1.0			1.0		
	No	1.2	0.6–2.3		1.4	0.7–2.8	
Installation of fan in bedroom	Yes	1.0			1.0		
	No	1.4	0.8–2.6		0.4	0.2–0.8	*
Lighting equipment	Light-emitting diode lamp	1.0			1.0		
	Light bulb	0.5	0.2–1.1		0.6	0.2–1.6	
	Fluorescent light	0.7	0.2–2.3		0.6	0.1–2.5	
3 Age (y)	20–59	1.0			1.0		
	⩾60	4.7	2.2–10.3	***	3.2	1.5–6.6	**
Gender	Men	1.0			1.0		
	Women	2.6	1.2–5.6	**	2.1	1.1–4.2	*
Self-rated health	Good	1.0			1.0		
	Poor	1.2	0.3–5.1		1.8	0.6–5.5	
Life satisfaction	Yes	1.0			1.0		
	No	1.1	0.4–2.7		2.6	1.1–6.0	*
Stress	No	1.0			1.0		
	Yes	1.1	0.5–2.6		0.9	0.4–2.1	
Bedroom		1.0			1.0		
Only for sleeping							
Bed cum sitting room		1.0	0.4–2.2		1.5	0.7–3.2	
Noise in the night	No	1.0			1.0		
	Yes	2.4	1.0–5.9	*	2.3	1.0–5.3	*
Installation of air conditioner in bedroom	Yes	1.0			1.0		
	No	2.5	1.2–5.1	*	1.0	0.5–2.1	
Installation of fan in bedroom	Yes	1.0			1.0		
	No	0.7	0.3–1.5		0.8	0.4–1.5	
Lighting equipment	Light-emitting diode lamp	1.0			1.0		
	Light bulb	0.6	0.2–2.0		1.3	0.4–4.5	
	Fluorescent light	0.6	0.1–3.0		2.2	0.5–10.1	
4 Age (y)	20–59	1.0			1.0		
	⩾60	3.7	1.3–10.1	*	1.6	0.7–3.6	
Gender	Men	1.0			1.0		
	Women	0.6	0.2–1.6		1.4	0.7–2.9	
Self-rated health	Good	1.0			1.0		
	Poor	9.0	2.8–28.7	***	2.3	0.8–6.8	
Life satisfaction	Yes	1.0			1.0		
	No	0.8	0.3–2.2		1.4	0.6–3.1	
Stress	No	1.0			1.0		
	Yes	2.3	0.7–7.3		2.5	1.1–5.8	*
Bedroom		1.0			1.0		
Only for sleeping							
Bed cum sitting room		2.3	0.9–5.6		1.6	0.8–3.5	
Noise in the night	No	1.0			1.0		
	Yes	8.8	3.1–25.0	***	2.4	0.9–5.7	
Installation of air conditioner in bedroom	Yes	1.0			1.0		
	No	2.8	1.1–7.1	*	1.9	0.9–4.1	
Installation of fan in bedroom	Yes	1.0			1.0		
	No	0.9	0.4–2.4		1.1	0.5–2.2	
Lighting equipment	Light-emitting diode lamp	1.0			1.0		
	Light bulb	0.9	0.2–4.5		0.5	0.2–1.3	
	Fluorescent light	0.5	0.1–4.9		0.5	0.1–2.2	

Abbreviations: DIS, difficulty initiating sleep; DMS, difficulty maintaining sleep; aOR, adjusted odds ratio; 95% CI, 95% confidence interval; y, years.
The reference of response variable is 1: not at all in 1 week.
(1 = not at all in one week; 2 = less than once a week; 3 = once or twice a week; and 4 = three or more times a week).
Significant differences were marked as *$P < .05$, **$P < .01$, and ***$P < .001$.

of disturbed sleep, as we did not estimate other objective indicators such as melatonin.

Our result is different from previous studies, which indicated that nocturnal short wavelength light exposure disturbed sleep [12], due to confounding such as personal characteristics. Although there were few participants who used LED lighting in our study, it has been spreading in the context of the energy policy of each country, which is attempting to reduce electricity consumption. LED lighting has the feature of easy control of spectral distribution and there are many LED lighting products which have a variety of wavelengths. Because there is the possibility of improving sleep quality by choosing adequate lighting equipment, further research about the association between daily light exposures from domestic lighting and daily sleep is needed.

4.3. Limitations of this study and future issues

4.3.1. Study design

Our study was a cross-sectional study which used a self-report questionnaire on subjective sleep status and residential environment. To estimate sleep, not only subjective but objective indicators are important. Further field research should focus on the association between objective sleep and thermal environment (e.g., use of cooling device, room or outside temperature, humidity) and light environment (e.g., hours of sunlight, domestic lighting equipment, intensity of illumination). We plan to conduct a survey measuring these variables and to observe them longitudinally.

4.3.2. Bias

Among the respondents, the percentage of older women was higher than that in the Japanese population (Table 1). Because the distribution of subjects selected by random sampling also was the same as the population, there were no problems with our selection method. Self-selection bias in which individuals who have sleep problems tend to respond to the questionnaire might arise, as it is known that the prevalence of insomnia is higher among older women [15,18]. On the other hand, the percentage of unavailable respondents was higher in the group of older women, and it might be that many older women who had sleep problem dropped out of the analysis. Therefore, sleep status in subjects could not reflect the entire population. However, our findings that the installation of an air conditioner and lighting equipment might affect sleep are useful for future discussions determining if sleep environment can improve sleep quality.

4.3.3. Regional characteristics

In our study, 90.0% of respondents lived in detached houses and 95.4% lived with their family. According to the national survey on Land and Housing [38], 91.2% of Japanese individuals lived in detached houses. Although the types of houses in the target area were similar to those all over Japan, the residential and sleep environment might be different in urban areas such as Tokyo where there are many apartments and many individuals living alone. In urban areas, there is more heat exposure at night because of the heat island phenomena, and we can expect the association between installation of air conditioners and sleep to be stronger. Further research should focus on other areas and try to examine the generalizability of our results.

Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2013.11.784.

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